Microstructure of Mg-Al Metal-Matrix Composite coatings by Casting-Penetration Process

Mingxing Hao[1], Liming Zhang[2] and Yongchun Wang[2]

[1] Jilin Province Chuncheng Heating Pipe Network Transportation Co., LTD, Changchun 130000, China;

[2]Jilin Province Chuncheng Heating Co., LTD, Changchun 130000, China.

Abstract

The objective of the present work is to study the interfacial microstructure and characterization of Mg-Al Composite coating made by casting penetration process. The morphology and microstructure of cross section of the Zn-Al alloy coatings were studied by scanning electron microscope (SEM) and energy dispersive X-ray spectroscopy (EDS); and an examination of the cladding using X-ray diffraction analysis (XRD) showed the formation of Mg-Zn eutectic phases as well as Mg-Al solid solution and alloyed phases such as Mg7Zn3 within the coating.

Keywords

Mg alloy, Composite coating, Microstructure, Casting-penetration.

1. Introduction

Magnesium is the lightest metallic structural material for addressing the issue of weight reduction in the aerospace and automotive and reducing greenhouse gas emissions [1]. However, their relatively poor corrosion resistances have restricted the widespread application of magnesium alloys. In order to further widen the application of magnesium alloys, surface modification has become an essential step to improve the surface anti-corrosion resistance property. Various surface techniques, such as PVD [2], chemical conversion coating [3], anodizing, thermal spray technology [4], chemical vapor deposition [5] and laser surface melting [6] are utilized for depositing the desired material on to the substrate to enhance the corrosion resistance of magnesium alloys. Zinc-aluminum alloys combine good physical characteristics, excellent mechanical properties, wear resistance and corrosion resistance [7-9].

In thsi study, the Zn-Al alloys coating was investigated using by casting-penetration process on AZ31 magnesium alloys. A surface coating for protecting the magnesium alloy substrate was obtained. Various morphologies of surface cladding and transition layer were observed. Microstructure, phases analyses and chemical composition were investigated.

2. Materials and Methods

2.1. Specimens preparation.

The chemical composition of Zn-Al metal sheet was composed of Zn 80 wt.% and Al 20 wt.%. The preparation process of Zn-Al alloy sheet, with dimensions of 60mm×25mm×1mm, was consist of grinding to remove the oxide films by emery papers up to 1500 grit, ultrasonically degreasing in acetone and finally put onto the bottom of a stainless steel mold for preheating under protection of argon gas. The AZ31 magnesium alloy, finally measured compositions of Al 3.15 wt.%, Zn 0.87%, and Mg the balance, is performed in a crucible electrical resistance furnace at 750 °C under protection of a mixed gas of SF_6 (1 vol.%) and CO_2 (balance). The completely

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melted alloy is manually stirred for 5min using a graphite impeller and stabilized for 30 min. The alloy liquids poured into the prepared stainless steel mold.

2.2. Microstructural characterization.

After the casting process, the specimens with Zn-Al alloy cladding were cross-sectioned by an electric spark machining. Microstructures were characterized by a scanning electron microscope (SEM; ZEISS EVO18, Germany) equipped with an energy dispersive spectrometer (EDS) analyzer (INCA-X-Max, England). Phase analysis of the samples was identified by X-ray diffraction (XRD; D/Max 2500PC, Rigaku, Japan) with Cu Kα radiation. The scanning range was 20° to 80°with a continuous scanning speed of 2° min-1, and the working voltage and current were 40 kV and 250 mA, respectively.

3. Results and Discussion

The SEM image of the cross-section morphology between Zn-Al alloy cast-penetrated cladding and AZ31 magnesium substrate is shown in Fig. 1. To investigate transition region microstructure, an excellent metallurgical bonding is formed between alloy cladding and AZ31 magnesium substrate. It demonstrates that cladding zone (CZ), diffusional zone (DZ), and bonding zone (BZ) are obtained in Fig. 1.

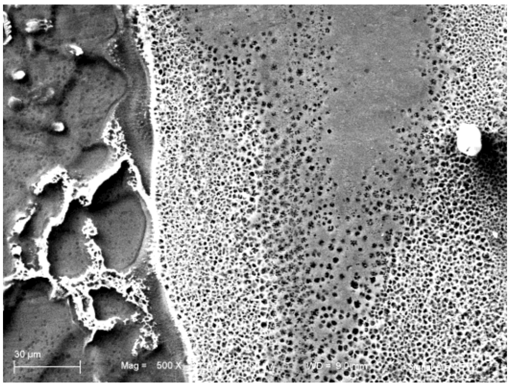

Fig. 1 SEM images of transition region of cast-penetrated cladding.

XRD patterns for AZ31 substrate and Zn-Al alloy cladding are seen in Fig.2. According to the Mg-Zn and Mg-Al binary alloy phase diagrams [10], The eutectic reaction temperature of Mg-Zn (at 340 °C) is lower than that of Mg-Al. When high temperature molten get into the Zn-Al alloy, Mg-Zn compounds were generated rapidly in the bonding zone due to the interdiffusion of zinc and magnesium atoms. However, Mg-Al eutectic phase appears by a eutectic reaction temperature at 437 °C [10]. Mg diffused into the dendrite zone at certain concentrations, $Mg_{0.71}Zn_{0.29}$ and Mg_7Zn_3 phases were formed under these conditons. With the increase of magnesium atom diffusion, dendrite structures were dissolved completely, and eutectic structures were generated. The formation of Mg-Zn compounds hindered the movement of Mg and Al atoms, the appearance of brittle and hard Mg-Al intermetallic compounds were avoided.

On the basis of the X-ray diffraction patterns as presented in Fig. 2, it indicates that the light dendritic structures are related to the aluminum-rich solution and the dark inter-dendritic structures are associated with the zinc-rich solution. These dendritic microstructures have been reported in previous literature [11]. In addition, the experimental results of previous research demonstrated the fine dendritic structure with more homogeneous distribution of eutectic mixture in grain boundaries and inter-dendritic regions improved the corrosion resistance [5].

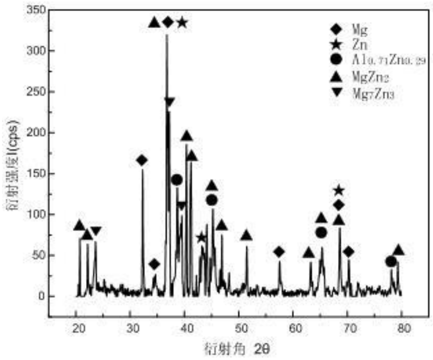

Fig. 2 XRD patterns of AZ31magnesium substraste and Zn-Al cast-penetrated cladding.

4. Conclusion

In the present work, the Zn-Al metal is designed to coat on AZ31 magnesium alloy surface by casting-penetration process. The experimental results indicated that an excellent metallurgical bonding cladding was formed between Zn-Al metal coating and AZ31 magnesium substrate. A lot of $Mg_{0.71}Zn_{0.29}$ and Mg_7Zn_3 phases are formed in the transition region. Microstructure demonstrates that the diffusion of magnesium atom and the changes of magnesium element concentration. And many eutectic structure and columnar eutectic structure present in the transition region.

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